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ABSTRACT

A prime concern of problem-solving instruction is to maximize positive transfer of learning from a previously solved problem to a new problem. One aspect of the relationship between transfer of learning and problem-solving instruction is the order of problem presentation. In this study, order of problem presentation is controlled, while certain inner-structure attributes of the problem tasks as well as the problem embodiment are varied systematically to determine their effect on transfer of learning to solve mathematical process problems. Ninety-four fifth graders were involved in the study; each was given two analogous mathematical process word problems to solve in a specific order of presentation, so that only one of the inner-structure attributes or the problem embodiment would differ. Transfer of learning was determined by three measures: (1) success/non-success at obtaining the correct answer; (2) time taken to answer correctly; and (3) observed strategies used by the student. The order of presentation (from less difficult to more difficult) produced positive transfer of learning but the most influential factor was the problem embodiment or wording. (Author/MNS)

ASPECTS OF TRANSFER OF LEARNING IN MATHEMATICAL PROBLEM SOLVING WITH RESPECT TO THE ORDER OF PROBLEM PRESENTATION

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ABSTRACT

A primary goal of mathematics educators is to find effective, efficient instructional methods for developing a student's ability to solve problems. A prime concern of problem-solving instruction is to maximize positive transfer of learning from a previousluy solved problem to a new problem. One aspect of the relationship between transfer of learning and problem-solving instruction is the order of problem presentation. Research in this area is con·erned with which order of problem presentation (more difficult-less difficult or less difficult-more difficult) accelerates learning by maximizing positive transfer of learning.

In this study, order of problem presentation is controlled, while certain inner-structure attributes of the problem tasks as well as the problem embodiment are varied systematically to determine their effect upon transfer of learning mathematical process problems.

INTRODUCTION

In recent years, mathematics educators have devoted more attention to problem-solving research than to any other field of inquiry. Why? Most of these educators believe that the ultimate purpose of studying mathematics is to improve a student's ability to solve problems. Thus, a primary goal of mathematics educators is to find effective, efficient instructional mtehods for developing this critical problem-solving ability.

One prime concern to developers of problem-solving instructional materials is promotion of transfer of learning; that is, the utilization of the solution process(es) from a previously solved problem to a new problem (Lester, 1980). A goal of problem-solving instruction is to maximize positive transfer of learning. One aspect of the relationship between transfer of learning and problem-solving instruction which has been studied is the order of problem presentation; namely, the sequence in which tasks are given to the student. Research in this area is concerned with which order of problem presentation (more difficult-less difficult or less difficult-more difficult) accelerates learning by maximizing positive transfer of learning. Findings of the research in this field of study are equivocal.

RELATED RESEARCH

A background study of analogy in transfer between a pair of problems by Reed, Ernst and Banerji (1974) reported that subjects exhibited positive transfer between a puzzle problem (Missionaries and Cannibals) and one of its homomorphs (Jealous Husbands) only when

the subjects were cued to the relationship between the two problems and only when the subjects solved the more difficult problem of the pair first.

Kulm and Days (1979) used an information-theoretic approach to study transfer between structurally related problems. They reported that transfer was significant when subjects solved an equivalent puzzle problem but not when subjects solved an equivalent algebraic problem. However, transfer was significant when subjects solved a similar algebraic problem but not when subjects solved a similar puzzle problem.

Silver (1981) reported that his study's findings are different from those of Reed, et al. His results indicated a significant transfer occurred only when the subjects solved the more difficult problem of a pair of process problems last. Silver, like Reed, cued his subjects to the relationship between the problems.

In spite of all the differences of the above-mentioned research studies, transfer from one problem to another seemed to occur only under certain requisites. This study investigates the effects of varying only one aspect of the task problem, namely the number of variables, or the number of conditions, or the cardinality of the solution space, or the problem embodiment.

STATEMENT OF THE PROBLEM

Four questions form the basis of this research study. Does any transfer of learning occur with respect to the order of presentation, between two process problems when:

1) the number of conditions, the cardinal size of the solution space, and the problem embodiment are all kept the same, but the number of variables in the problem is changed?

2) the number of variables, the cardinal size of the solution space, the problem embodiment are all kept the same, but the number of conditions in the problem is changed?

3) the number of variables, the number of conditions, and the problem embodiment are all kept the same, but the cardinal size of the solution space is changed?

4) the number of variables, the number of conditions, and the cardinal size of the solution space are all kept the same, but the problem embodiment is changed?

DEFINITIONS

1. A condition in a process problem is an overt restricting or modifying factor in a problem.

2. Mathematical inner structure factors of a problem are defined as: 1) the variables in a problem, 2) the conditions in a problem, and 3) the solution space of the problem.

3. Order of problem presentation is the sequence in which a series of problems is given to the subjects.

4. A problem embodiment is the written and/or verbal setting of the problem.

5. A solution space of a problem is the set of elements in the union of the sets of possible natural number solutions for each condition in a problem.

6. (a) Transfer of learning -- conceptual definition: Transfer of learning in mathematical problem solving is defined as the utilization of the solution processes of a previously solved problem to solve a new problem.

(b) Transfer of learning -- operational definition: Transfer of learning in mathematical problem solving is defined as a measurable change in either: 1) the percentage of correct responses from one problem to an analogous problem; or 2) the average time taken to find a correct solution from one problem to an analogous problem.

7. A variable in a process problem is an unknown, the value of which is not expressly given in the problem.

THE INSTRUMENT

Basic Problem Ba: Sam has $1.65 in nickels and quarters.
He has 9 coins in all.
How many coins of each kind does Sam have?

Analogous Problem V: Sam has $.65 in nickels, dimes and quarters.
He has 6 coins in all.
How many coins of each kind does Sam have?

Analogous Problem C: Sam has $1.25 in nickels and quarters.
He has 9 coins in all.
If he had twice as many nickels and three times the number of quarters, he would have 22 coins.
How many coins of each kind does Sam have?

Analogous Problem S: Sam has $2.35 in nickels and quarters.
He has 19 coins in all.
How many coins of each kind does Sam have?

Analogous Problem E: Mr. Smith has 165 pounds of candy in five pound boxes and in twenty-five pound boxes in his store.
He has 9 boxes in all.
How many boxes of each size does Mr. Smith have?

THE INSTRUMENT'S INNER-STRUCTURE ATTRIBUTES AND EMBODIMENT

	PROBLEMS				
	Ba	V	C	S	E
Number of Variables	2	3	2	2	2
Number of Conditions	2	2	3	2	2
Solution Space Size	13	13	13	26	13
Embodiment Same as Ba	yes	yes	yes	yes	no

METHODS

Procedures in this study involved individual clinical interviews with ninety-four fifth grade students. Each subject was given (and read to) two analogous mathematical process word problems to solve in a specific order of presentation. These orders of presentation were either Ba-V, V-Ba, Ba-C, C-Ba, Ba-S, S-Ba, Ba-E, or E-Ba. Therefore, only one of the inner-structure attributes or the problem embodiment would differ in each pair of tasks given to a student. Subjects were instructed to show their work. After the subjects finished the two problems, they were questioned for retrospective analysis of their thinking processes. Transfer of learning was determined by three measures: success/non-success at obtaining the correct answer, time taken by the subject to answer correctly, and observed strategies used by the subject.

DATA

Change in Correct Answer Performance of Each Analogous Problem in the Less Difficult-More Difficult Order of Presentation

V	C	S	E
24% increase	11% increase	64% decrease	644% increase*

*significant at p § .003 level

Change in Correct Answer Performance of the Basic Problem (Ba) in the More Difficult-Less Difficult Order of Presentation

V-Ba	C-Ba	S-Ba	F-Ba
7% decrease	9% decrease	29% increase	57% decrease*

*significant at p § .20 level

Correct Answer Percentage with Respect to the Order of Presentation of Problems Ba & Analogous Collapsed

	Ba-Analogous	Analogous-Ba	Result Effect
Ba	70%	58%	17% decrease
Analogous	46%	27%	70% increase*

*significant at p § .062 level

CONCLUSIONS

If the analogous problems, V, C, S, and E, are considered to be more difficult problems to solve than the basic problem Ba, (because of the more complex inner-structure attributes, and/or the lower correct answer percentages, and/or the longer average solution times, and/or the subjects' identification of problem difficulty) the less difficult-more difficult order of presentation increased the correct answer performance of the analogous problems by a significant 70%. That is, the order of presentation less difficult-more difficult produced a significant positive transfer of learning.

However, this is a surface analysis of the research. The more systematic approach of isolating the individual inner-structure attributes provides a clearer picture of the situation. Individually, concerning the number of variables of problems, it seems that the less difficult-more difficult order of problem presentation results in some positive transfer of learning. The same is true concerning the number of conditions. However, the opposite appears to be true concerning the cardinal size of the solution space. Thus, for homomorphic problems, it may be that the inner-structure attributes of the number of variables and conditions conflict with the inner-structure attribute of solution space size in the transfer of learning.

Yet, far and away the most influential factor was the problem embodiment. Presenting the less difficult problem Ba first resulted in a significant (p § .003) positive transfer of learning for problem E. Since the problems Ba and E are isomorphic, it might be assumed that any change in the order of presentaion would be insignificant.

This definitely is not true. The change of a problem's embodiment, or wording, greatly affects the level of the problem's difficulty and the possiblities for positive transfer of learning. What this research study has shown is that just classifying problem tasks as homomorphic or isomorphic is not adequate. The inner-structure attributes and the problem embodiment must also be addressed.

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